AD-A046 774   CALIFORNIA UNIV LOS ANGELES DEPT OF PSYCHIATRY   F/G 6/2
BIOFEEDBACK AND SELF-REGULATION IN ESSENTIAL HYPERTENSION.(U)
SEP 77 D SHAPIRO, J A MAINARDI, R S SURWIT   N00014-75-C-0150

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TECHNICAL REPORT NO. 8

September 20, 1977

BIOFEEDBACK AND SELF-REGULATION IN ESSENTIAL HYPERTENSION

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Prepared for:

Office of Naval Research
Physiology Program, Environmental Physiology
Contract N00014-75-C-0150

Research sponsored by Office of Naval Research under Contract N00014-75-C-0150, NR 201-152.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) TR 8 - 9-20-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) BIOFEEDBACK AND SELF-REGULATION IN ESSENTIAL HYPERTENSION.		5. TYPE OF REPORT & PERIOD COVERED Interim thru 9/20/77
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) David Shapiro, J. Alberto Mainardi, Richard S. Surwit (Harvard Medical School)		8. CONTRACT OR GRANT NUMBER(s) (15) N00014-75-C-0150
9. PERFORMING ORGANIZATION NAME AND ADDRESS Regents of the University of California UCLA, 405 Hilgard Avenue Los Angeles, Ca. 90024 (Dept. of Psychiatry)		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 201-152
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research (Code 441) Department of the Navy Arlington, Virginia 22217		12. REPORT DATE (11) 20 Sep~~tember 20~~, 1977
		13. ~~NUMBER OF PAGES~~ 35
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (9) Interim rept. for period ending 20 Sep 77		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

(12) 38p.

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release; distribution unlimited

18. SUPPLEMENTARY NOTES

Chapter 13 in G. E. Schwartz & J. Beatty (Eds.), Biofeedback: Theory and Research. New York: Academic Press, 1977.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Biofeedback
Operant conditioning
Behavioral factors in hypertension
Relaxation
Meditation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Hypertension is a major public health problem because of its association with life-threatening disorders. A large body of evidence indicates that psychosocial and behavioral factors may play a significant role in the development and maintenance of high blood pressure, mediated by the autonomic nervous system. Behavioral treatment approaches such as biofeedback may offer a nonpharmacological means of lowering blood pressure levels, enhancing drug treatment of the disease, and fostering compliance with treatment.

This paper consists of a review of basic biofeedback research on the control

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S/N 0102-014-6601

409 651

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Block 20. Abstract, Contd.

of human blood pressure, a presentation of the clinical studies on the application of biofeedback methods to treatment of hypertension, and a summary of related clinical research on other methods of self-regulation for the disorder. Medical and physiological facts about the disorder and of importance to behavioral approaches are presented. Practical clinical issues which complicate the application of biofeedback are discussed.

It is concluded that biofeedback and other behavioral procedures may provide alternative or adjunctive modalities in the treatment of high blood pressure. In several studies, biofeedback techniques appear to be effective in reducing pressure levels or in reducing medication requirements. However, the clinical research is incomplete, and more comprehensive studies are needed to evaluate the long-term effects and feasibility of biofeedback and other methods of behavioral and self-regulation in essential hypertension.

REPRINTED FROM
BIOFEEDBACK
Theory and Research

ACADEMIC PRESS, INC.
NEW YORK SAN FRANCISCO LONDON

13

Biofeedback and Self-Regulation in Essential Hypertension*

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Hypertension is a major public health problem in the United States, estimated to occur in 5% to 10% of the general population. High levels of arterial blood pressure increase the risk of life-threatening disorders such as coronary artery disease, atherosclerosis, and nephrosclerosis (Kannel, Gordon, & Schwartz, 1971). Even occasional large increases in resting levels of pulse rate and blood pressure are thought to be associated with a shortening of the life span (Merrill, 1966). A vast proportion of all cases of hypertension are diagnosed as "essential hypertension," defined by idiopathic elevations in blood pressure. While investigators do not entirely agree about the significance of psychological factors in hypertension, incidence of the disorder ap-

* Supported by National Institute of Mental Health Research Grants MH-26923 and MH-25104, Training Grant MH-06415, and Office of Naval Research Contract N00014-75-C-0150. Portions of this chapter were adapted from D. Shapiro and R. S. Surwit, "Learned control of physiological function and disease," in H. Leitenberg (Ed.), *Handbook of behavior modification and behavior therapy* (Englewood Cliffs, N.J.: Prentice-Hall, 1976).

pears related to various behavioral, social, and environmental conditions (Gutmann & Benson, 1971). A good body of literature indicates that such environmental factors play a critical "triggering" role in the development of the disorder. Excessive reactivity of the sympathetic nervous system may be associated with elevations of blood pressure in the early stages of hypertension as evidenced by increases in heart rate, cardiac output, and cardiac contractility (Frohlich, Tarazi, & Dustan, 1969; Frohlich, Ulrych, Tarazi, Dustan, & Page, 1967; Julius & Conway, 1968). This reactivity probably occurs in individuals who are particularly susceptible by reason of genetic, constitutional, or other factors. In addition, recent evidence indicates that there are interactions between autonomic and renin-angiotensin systems which play a significant role in hypertension (Buñag, Page, & McCubbin, 1966; Davis, 1971; Ganong, 1973; Stokes, Goldsmith, Starr, Gentle, Mani, & Stewart, 1970; Ueda, Kaneko, Takeda, Ikeda, & Yagi, 1970; Ueda, Yasuda, Takabatake, Iizuka, Iizuka, Ihori, & Sakamoto, 1970).

Current medical practice advocates active treatment when there is reason to suspect that the hypertension is becoming severe and fixed (Freis, 1974; Merrill, 1966; Veterans Administration Cooperative Study Group on Antihypertensive Agents, 1967, 1970, 1972). In view of assumed environmental, personality, and autonomic nervous system components of essential hypertension, biofeedback or other behavioral approaches offer nonpharmacologic means of lowering pressure that can augment or facilitate methods in medical practice. Two important problems in the management of hypertension, besides detection and diagnosis, are effectiveness of drug therapy and treatment compliance. Behavioral treatments such as biofeedback may be important in cases where drug control is not adequate or results in disturbing side effects. They can be used as adjuncts to drug therapy in order to provide more adequate control of blood pressure levels or to reduce required dosage. Behavioral treatments offer alternatives for patients who do not want to comply with drug treatment, for whatever reasons, in the same way that drug treatment offered an alternative for patients who did not want to undergo sympathectomy in the early 1950s. Behavioral treatments may expand the number of treated patients, aid in prevention, and help make patients more aware of responsibility for their health.

BIOFEEDBACK AND BLOOD PRESSURE REGULATION: BASIC RESEARCH

Basic research on biofeedback in the regulation of blood pressure provides evidence for the extension of such techniques into a

therapeutic setting. In the curarized rat, instrumental conditioning of systolic blood pressure was demonstrated using shock escape and avoidance (DiCara & Miller, 1968). Learned changes in pressure were about 20% of baseline in both increase and decrease directions, and they were not associated with changes in heart rate or rectal temperature. In a subsequent study in noncurarized rats, changes obtained were about 5% of baseline (Pappas, DiCara, & Miller, 1970). Diastolic pressure elevations of large magnitude (50–60 mmHg) were obtained in the rhesus monkey using a shock avoidance procedure in which the elevations functioned as an avoidance response (Plumlee, 1969). More modest elevations of mean arterial pressure (25 mmHg) were observed in the squirrel monkey using similar procedures (Benson, Herd, Morse, & Kelleher, 1969). In the dogfaced baboon, substantial elevations in blood pressure were established by an operant procedure in which food delivery and shock avoidance were made contingent upon increases in diastolic pressure (Harris, Findley, & Brady, 1971; Harris, Gilliam, Findley, & Brady, 1973). In their recent work, these investigators reported sustained increases of about 30–40 mmHg in both systolic and diastolic blood pressure. The changes in blood pressure were associated with elevated, but progressively decreasing, heart rates (Harris & Brady, 1974).

Having an experimental animal with behaviorally induced hypertension is of significance for the study of associated physiological and biochemical processes, and it suggests that the illness may develop in this fashion. Arterial blood pressure in squirrel monkeys can be modulated in characteristic ways by different operant conditioning schedules, and sustained hypertension can be associated with schedule-controlled performances (Morse, Herd, Kelleher, & Grose, 1971). In exploring the value of an operant conditioning therapy in squirrel monkeys, Benson *et al.* (1969) put them on a work schedule in which they were required to press a key in order to avoid electric shock. Prolonged and persistent elevations in pressure resulted. Then, the schedule was reversed, and a decrease in pressure became the criterion for shock avoidance. Pressures were shown to decline 10 to 20 mmHg. However, the capacity to reduce blood pressure using an operant procedure may be related to the length of time that the high level is present (Teplitz, 1971). It is not known whether or not similar reversals can occur in animals with chronic high levels of pressure.

Most of the human studies on blood pressure control with biofeedback methods follow the procedures first described in Shapiro, Tursky, Gershon, and Stern (1969). The "constant cuff" technique was devised to obtain a relative measure of blood pressure on each beat of the heart so as to be able to provide continuous feedback to subjects.

Intermittent measurements (once or twice a minute) using an ordinary pressure cuff (Riva-Rocci method) can provide information on only 2% to 3% of the changes. They are inadequate because of the inherent variability of blood pressure. A single determination of systolic or diastolic pressure every half-minute can vary by chance as much as 20–30 mmHg from typical values. For example, in a minute's direct recording of pressure obtained via an arterial catheter, two successive casual clinical measurements using a standard cuff procedure would have yielded 124/90 and 144/60 mmHg, while the median reading based on the 50 pressure waves was actually 128/68 mmHg (Tursky, Shapiro, & Schwartz, 1972). Direct arterial catheterization is not a feasible alternative for routine repetitive training, although it may be possible in some hospitalized patients.

In the constant cuff method, a blood pressure cuff is wrapped around the upper arm, and a crystal microphone is placed over the brachial artery under the distal end of the cuff. The cuff is inflated to about average systolic pressure and held constant at that level. Whenever the systolic pressure rises and exceeds the occluding cuff pressure, a Korotkoff sound is detected from the microphone. When the systolic level is less than the occluding pressure, no Korotkoff sound is detected. Using a regulated low-pressure source and programming apparatus, it is possible to find a constant cuff pressure at which 50% of the heart beats yield Korotkoff sounds. This pressure is, by definition, median systolic pressure. Inasmuch as the time between the R-wave in the electrocardiogram and the occurrence of the Korotkoff sound is approximately 300 milliseconds, it is possible to detect either the presence of the Korotkoff sound (high systolic pressure relative to the median) or its absence (low systolic pressure relative to the median) on each heart beat. In this way, the system provides information about directional changes in pressure relative to the median on each successive heart beat, and this information can be used in a biofeedback procedure. Subjects are provided with binary (yes–no) feedback of either relatively high, or low, pressure on each heart beat. After a prescribed number of feedback stimuli or a change in median pressure, rewarding slides or other incentives are presented.

The cuff is inflated for a trial period of 50 heart beats and then deflated for about 30 seconds to allow recirculation of the blood. Whenever the percentage of Korotkoff sounds in a single 50-beat trial is greater than 75% or less than 25%, the constant pressure is increased or decreased in the next trial by a small amount (±2 mmHg) to return the cuff pressure to the subject's median. In addition to providing blood pressure feedback on each heart beat, the system can also track

median pressure from trial to trial. The system has been evaluated against simultaneous data obtained using a direct arterial recording, and a close correspondence has been obtained for all of its essential features (Tursky *et al.*, 1972). Comparable procedures are used to determine diastolic values. In this case, the cuff is set at a constant pressure close to the median diastolic level, and the presence or absence of the Korotkoff sound at this level is used to track median diastolic pressure.

Some investigators have used the same constant cuff procedure but with a smaller number of heart beats per trial (Goldman, Kleinman, Snow, Bidus, & Korol, 1975; Kristt & Engel, 1975;. For further information on the constant cuff method and other methods of indirect recording of human blood pressure, see Tursky (1974). Efforts are currently under way to develop a simple portable blood pressure biofeedback device that can be used in the doctor's office or in the home.

Initial studies with the constant cuff method attempted to determine whether normal volunteer subjects could learn to modify their systolic or diastolic blood pressure. Complete details of the experiments may be found in Shapiro *et al.* (1969), Shapiro, Tursky, and Schwartz (1970a,b), Schwartz, Shapiro, and Tursky (1971), Schwartz (1972), and Shapiro, Schwartz, and Tursky (1972). In these studies, subjects were told that the feedback represented information about "a physiological response usually considered involuntary." Subjects were simply told to make the feedback stimulus occur as much as possible and thereby to earn as many rewards as possible. They were not told that the feedback was being given for changes in blood pressure; nor were they told whether to increase it or decrease it. This procedure controlled for any results that are due to the natural ability of subjects to control their pressure "voluntarily," and tested the specific effects of feedback and reward contingency. Voluntary control of blood pressure and other circulatory changes has been reported in individual cases (Ogden & Shock, 1939) and may be more widespread than previously believed. However, voluntary control of blood pressure unassisted by external feedback was not obtained, on the average, in a sample of normal subjects (Shapiro, 1973). Brener (1974) has also reported failure to obtain blood pressure control with instructions only.

To summarize these studies, normal subjects were able to modify their blood pressure with feedback and reward. Average differences in systolic pressure between increase and decrease conditions for groups of subjects at the end of a single session of training varied from 3% to 10% of baseline. The best results were obtained for diastolic pressure

(Shapiro *et al.*, 1972) with individuals showing increases up to 25% and decreases up to 15% of baseline values. Heart rate was not associated with learned changes in systolic pressure, and systolic pressure was not associated with learned changes in heart rate (Shapiro *et al.*, 1970b). However, Fey and Lindholm (1975), using the constant cuff method, reported that heart rate increased or decreased in groups receiving contingent feedback for increasing and for decreasing systolic blood pressure, respectively. Brener (1974) cited data from a dissertation by Emily M. Shanks in which continuous recordings of heart rate, chin electromyogram, and respiratory activity were obtained while subjects were given both increase and decrease feedback training for diastolic blood pressure. The results indicated that diastolic blood pressure biofeedback tended to have an effect specific to blood pressure (see also Brener & Kleinman, 1970). However, Shapiro *et al.* (1972) reported that heart rate was not independent of learned changes in diastolic pressure. Clearly, the evidence on specificity of learned blood pressure control is not entirely consistent.

To explain the conditions under which specificity of conditioning occurs, Schwartz (1972) hypothesized that when feedback is given for one response, simultaneous learning of other responses will depend on the degree to which these other responses are directly associated with the response for which feedback is given, as well as on other homeostatic mechanisms. He developed an on-line procedure for tracking both phasic and tonic patterns of blood pressure and heart rate in real time and showed that subjects could learn to control patterns of simultaneous changes in both functions. Subjects learned to integrate systolic blood pressure and heart rate (i.e., make both increase or both decrease simultaneously) and to some extent to differentiate both functions (i.e., make one increase and the other decrease simultaneously). Further analysis of the patterning of both functions over time and of natural tonic reactivity in this situation made it possible to predict the extent and time course of pattern learning in the different conditions. Subjective reports of a "relaxed" state were associated with learned reduction in both systolic pressure and heart rate (see also Schwartz, 1975).

Although the average curves suggest that it is easier to obtain reductions than increases in pressure in a single session (Shapiro *et al.*, 1969), further data under conditions of random reinforcement indicated a tendency for baseline pressure values to habituate over time (Shapiro *et al.*, 1970a). Therefore, increases in pressure over baseline values may be more likely in normal subjects. Unpublished data (Shapiro) indicated that the same pattern of pressure reduction occurs

whether subjects try to reduce their pressure with or without feedback or simply rest in the laboratory and do nothing. On the other hand, Fey and Lindholm (1975), using the constant cuff method, reported reliable decreases in systolic blood pressure over three 1-hour sessions of feedback training for reduced pressure as compared with no changes in no-feedback, random, or increase-training groups. As in the case of heart rate, the processes involved in increasing blood pressure may be different from those involved in decreasing pressure (see Engel, 1972; Lang & Twentyman, 1974). In normal subjects, typical resting pressures are close to minimal waking values, but there is a potential for large increases above baseline. For individuals having significantly elevated pressure levels, significant decreases may be more likely.

By and large, uninstructed normal subjects, though they were able to produce changes in blood pressure, could not consistently report whether they were, in fact, learning to raise or lower their pressure; nor did they report the consistent use of specific thoughts, images, or physical strategies, such as respiratory maneuvers or muscle tension, as a means of achieving control. The determination of effective related strategies of control would be useful in practical applications of biofeedback methods, and additional research is needed to examine associated physiological and cognitive processes in detail.

Finally, Brener and Kleinman (1970) used a finger-cuff method of following systolic pressure. In an experimental group, normotensive subjects were instructed to decrease their blood pressure with the aid of pressure feedback. In a control group, subjects were instructed to observe the feedback, but they were not informed of its meaning. Differences of about 20–30 mmHg were obtained between the two groups after about 30 minutes of training, and the differences were not associated with heart rate. Inasmuch as blood pressure values obtained with a finger cuff are larger than those obtained with an arm cuff, it is difficult to compare these results with the smaller changes reported previously (Shapiro *et al.*, 1969).

All told, this research suggests that blood pressure can be self-regulated by normal subjects with a fair degree of consistency and specificity. The degree of change achieved, especially in a decrease direction, is relatively small. However, most of the research consists of one-session experiments in subjects already low in pressure to begin with. More work is needed to determine whether larger and persistent changes can be brought about with long-term training. In addition, further research is needed on the biofeedback regulation of other cardiac and vasomotor functions (e.g., cardiac output, heart contractile force, blood flow in muscles and other organs) as well as a more com-

prehensive physiological and hemodynamic assessment of changes taking place in blood pressure feedback studies. We should also investigate the effects on blood pressure and other cardiovascular indices when subjects are given biofeedback training for reductions in activity at various muscle sites, for reductions in electrodermal activity and other autonomic functions, for changes in various respiratory indices, and for alterations in various brain wave rhythms. Aside from these physiologically oriented questions, investigation has to proceed further into the effects of different behavioral and psychological factors in association with and comparison to biofeedback training. These include the use of particular instructions or training sets, suggestion, imagery, cognitive processes, incentives, reinforcers, and individual or personality differences. Clearly, there are great holes in our basic knowledge of self-regulatory psychophysiological processes, not only with respect to blood pressure control but also to other, related processes. To a large extent, clues concerning the direction of such basic research will derive from a variety of perspectives and from the clinical research, described below, which is rapidly accumulating observations and critical questions. Answers to these questions will permit a more rational and comprehensive approach to clinical application.

CLINICAL APPLICATIONS OF BLOOD PRESSURE BIOFEEDBACK IN HYPERTENSION

The basic laboratory data provided a foundation for the clinical application of biofeedback to hypertension. Benson, Shapiro, Tursky, and Schwartz (1971) used feedback techniques in the lowering of systolic blood pressure in seven patients, five of whom had been diagnosed as having essential hypertension. Medication dosage, diet, and other factors were kept constant during the course of the study. Of the two other patients, one did not have elevated systolic pressure and the other had renal artery stenosis. No reductions were observed in as many as 15 pretreatment control sessions. The five patients responding positively showed decreases of 34, 29, 16, 16, and 17 mmHg with 33, 22, 34, 31, and 12 sessions of training, respectively. The two patients diagnosed as not having essential hypertension showed little or no decrease in systolic pressure as a result of the conditioning procedure. Inasmuch as no reliable pressure readings were taken outside of the laboratory, the general effectiveness of the training could not be determined.

In the Benson *et al.* study (1971), the average amount of within-

session decrease in systolic pressure for the patients was about 5 mmHg, about the same as in studies of normal subjects. Although the lowered pressure tended to carry over from one session to the next, the trends were not always consistent. Curves of individual patients suggested a pattern of successive cycles of decreasing pressure interspersed with increases and subsequent decreasing trends. Apparently, certain events in the life of the patient, or other factors not presently understood, interfered with the process of self-regulation. The pressure would bounce back, although not to original levels, and then the pattern of pressure reduction would resume. The feedback-reward techniques may facilitate a process of habituation. It is not entirely clear whether random feedback, attempts at voluntary control without feedback, muscular relaxation, or simply sitting in the laboratory would not achieve comparable results in patients with high blood pressure (see below).

It is important to have well-established, stable baseline values in clinical studies such as these. For example, patients may overrespond to initial sessions with higher than typical pressures for themselves. Subsequently, reductions in pressure would be observed as patients got used to the laboratory situation. Such reductions may be misinterpreted as a therapeutic effect. In the Benson *et al.* (1971) study, little or no reduction in pressure was observed in these patients after as many as 15 control sessions under resting conditions with no feedback or rewards. However, nonspecific placebo effects cannot be ruled out as an explanation of the observed reductions in pressure. The patients studied had been in treatment for hypertension for long periods of time, and no changes in their drug treatment were made. The innovation of "biofeedback" as a new technique involving unusual instrumentation, feedback displays, and the idea of self-control may be a very good placebo (Stroebel & Glueck, 1973).

Parenthetically, there is nothing wrong with placebo effects. Indeed, Miller (1974) cites a number of studies in which powerful effects on physiological responses, including blood pressure, could be obtained by pill placebos and simple suggestions. Such phenomena are well known, although insufficiently studied or understood in terms of mechanism (see A. K. Shapiro, 1960). Moreover, they underscore the potential for human beings to bring their blood pressure under control without active medication and simply through psychological mechanisms. In the final analysis, the value of any procedure in medicine depends upon how effective and for how long it can bring the symptom and the illness under control. Clearly, the better we under-

stand mechanisms of therapeutic effects, including placebo effects, the more probable it is that the benefits will be long-lasting and significant.

Using the constant cuff procedure, Goldman *et al.* (1975) reported average decreases of 4% and 13% in systolic and diastolic pressure, respectively, in seven patients with average baseline values of 167/109 mmHg who were diagnosed as having essential hypertension and who were willing to participate in the study prior to having medication. Although feedback was given for systolic pressure, the significant reductions occurred only in diastolic pressure over the course of the nine training sessions. Those patients who showed the greatest decreases in both systolic and diastolic pressure during biofeedback training also showed the greatest improvement on the Category Test of the Halstead–Reitan Neuropsychological Test Battery for Adults (Reitan, 1966). As this test is related to cognitive dysfunctioning, Goldman *et al.* speculate that biofeedback may be useful in lowering pressure *and* in overcoming a cognitive impairment associated with hypertension. This kind of impairment has been suggested in previous research (Reitan, 1954; Richter-Heinrich & Läuter, 1969). Moreover, the improvement in cognitive functioning suggests that the effects of biofeedback training may not be entirely laboratory-specific. The need for further evaluation of independent criteria of the results of treatment, including cognitive, social, and psychological factors as well as the critical medical and physiological changes, is obvious.

Miller (1975) attempted to train 28 patients with essential hypertension to reduce their diastolic blood pressure. A few patients appeared to reduce their blood pressure, but, after reaching a plateau, the pressure drifted up again. One patient showing good results was trained to alternate in increasing and decreasing her pressure. Over a period of 3 months, this patient acquired the ability to change pressure over a range of 30 mmHg. Her baseline pressure decreased from 97 to 76 mmHg, and similar decreases were observed on the ward; medication was discontinued. Later on, she lost voluntary control and was put back on drugs as a result of life stresses. When the patient came back to training 2½ years later, she rapidly regained a large measure of control. Such multiple courses of treatment need to be done more often and evaluated thoroughly.

Kristt and Engel (1975) reported evidence that patients with essential hypertension having a variety of cardiovascular and other complications can learn to control and reduce their pressure over and above the effects produced by drugs. In Phase 1, the patients took their pressure at home daily over a 7-week period and mailed in their re-

ports to the laboratory. In Phase 2, patients were trained to raise, to lower, and to alternately raise and lower systolic blood pressure. The constant cuff method (Shapiro *et al.*, 1969) was used to record pressure and provide feedback. In Phase 3, the patients again took their pressure at home and mailed in daily reports. Learned control of pressure was observed in all patients during the training sessions, and reductions in pressure of about 10%–15% were observed from pretraining baselines to values recorded at a 3-month follow-up. Although feedback training was provided for systolic pressure, diastolic pressure was also reduced. Medication was reduced in three patients, including one patient whose blood pressure had been progressively rising which would have otherwise required a change in the medication schedule. This study is particularly relevant because it shows that biofeedback can be used to provide direct control of blood pressure in the laboratory and at home, even in patients with cardiovascular complications such as cardiac arrhythmias, left ventricular hypertrophy, malignant hypertension, aortic atherosclerosis, cardiomegaly, and diabetes. It also shows that biofeedback can at least aid in the management of hypertension by reducing the dosages required to control blood pressure. At least in some patients, biofeedback may be used as a successful substitute for and/or an adjunct to antihypertensive medication.

Since systolic blood pressure has been found to be more closely associated with morbidity and mortality than diastolic pressure in males over 45 years of age, reductions in systolic pressure could be a treatment of choice for this particular age–sex population. Also, morbidity and mortality in females seem to be more dependent upon systolic than diastolic pressure at almost all ages (Kannel *et al.*, 1971). In younger men, diastolic pressure is more closely associated with morbidity and mortality (Kannel *et al.*, 1971), in agreement with traditional concepts of hypertension (Merrill, 1966). Diastolic pressure is thought to be more critical in later or final stages of hypertension because of its closer relation to peripheral resistance (Merrill, 1966). Preliminary research (Benson, Shapiro, & Schwartz, unpublished) suggests that it is difficult to reduce abnormally high diastolic levels in patients with hypertension (see Schwartz & Shapiro, 1973). Part of the problem may be related to unreliability in obtaining consistent diastolic values over repeated sessions. Learned control of diastolic pressure was observed in a single-session study of normal subjects, with consistent changes occurring in almost all subjects (Shapiro *et al.*, 1972). However, positive results of biofeedback training for decreases in diastolic pressure in patients have been reported in other labora-

tories. Using feedback and verbal praise, 20%–30% reductions in diastolic pressure were obtained in patients diagnosed as essential hypertensives (Elder, Ruiz, Deabler, & Dillenkoffer, 1973). None of the 18 patients studied was under antihypertensive medication, although many were on central nervous system depressants. As discussed previously, other clinical studies have reported significant reductions in diastolic pressure, even though the feedback training was related to control of systolic pressure.

Surwit and Shapiro (in press) report preliminary findings of a clinical study in which two types of biofeedback training were compared to a form of meditation in the treatment of borderline hypertension. The subjects were 24 borderline hypertensives, who were evenly divided into three treatment conditions. All subjects received two 1-hour baseline sessions and eight hour-long biweekly treatment sessions. The first treatment group received binary feedback for simultaneous reductions of blood pressure and heart rate (Schwartz, Shapiro, & Tursky, 1972). The second group received analogue feedback for combined forearm and frontalis electromyographic activity. The third group received a meditation–relaxation procedure (Benson, 1975). Six weeks following the last treatment session, all subjects received a 1-hour treatment follow-up session. Preliminary analysis indicates that all three treatment groups showed significant reductions in pressure over trials during each session, implying that each of the behavioral methods tested was equally effective as a clinical intervention. Carry-over effects from session to session or in follow-up evaluations were not significant. Borderline or labile patients may reveal normal pressure levels in a quiet laboratory, suggesting that the conditions of training may not be appropriate for retraining purposes. Related to this issue, high levels of pressure may be under the control of particular situational events, and patients would therefore need to learn to reduce their reactivity in relation to such triggering stimuli.

The above clinical studies provide supportive evidence concerning the potential of biofeedback techniques in the direct reduction of blood pressure in patients with essential hypertension. Similar biofeedback procedures have been used in independent laboratories with relatively consistent positive results. However, wide differences exist in characteristics of patients studied, duration of treatments, availability of follow-up data, and amount of systematic documentation of physiological effects and changes in drug regimes. The total number of patients studied is still few, and only large-scale clinical trials accompanied by comprehensive medical, physiological, and psychological evaluations can provide the information required before biofeedback can be routinely applied in essential hypertension.

OTHER BIOFEEDBACK AND SELF-REGULATION METHODS

The clinical studies discussed above attempted direct control of blood pressure by means of blood pressure feedback. Other approaches have been investigated that involve biofeedback of physiological responses assumed to be associated with blood pressure. These approaches are based on the belief that reductions in response levels of associated functions will bring about concomitant reductions in blood pressure. Other behavioral methods not involving the use of complex feedback techniques include progressive relaxation, meditation, yogic practices, autogenic training, and suggestion.

Patel (1973) used a combination of yogic relaxation and electrodermal (GSR) feedback in a group of 20 patients (11 women and 9 men) of mixed diagnostic categories (essential, renal, and intracranial hypertension, and essential hypertension following toxemia of pregnancy). All patients were under antihypertensive medication at the beginning of the trial. Their ages varied from 39 to 78 years with an average of 57. When they were first found to be hypertensive, systolic pressure varied from 160 to 230 mmHg (average 190), and diastolic pressure varied from 100 to 150 mmHg (average 122). When the patients entered the trial, systolic pressure varied from 130 to 190 mmHg (average 160), and diastolic pressure varied from 88 to 113 mmHg (average 102). The duration of hypertension varied from 1 to 20 years (average 6.8 years). Before entering the trial, any attempt to reduce drug dosage increased blood pressure. The study consisted of half-hour sessions, three times a week, for a period of 3 months. At the conclusion of the study, antihypertensive medication was discontinued in 25% of the patients, and reduced by 33% to 60% in seven other patients. Blood pressure control was better in four other patients, while four patients did not respond to therapy. Patel (1975), reporting on a 12-month follow-up in the patients previously studied, concluded that both blood pressure and drug reductions were maintained. Moreover, in a control procedure involving simple blood pressure measurement and regular medical care, no significant reductions in blood pressure were observed. The rationale for using electrodermal feedback is not entirely clear, but its effectiveness may depend upon its role in facilitating relaxation by lowering sympathetic nervous system function. Altogether, from a practical standpoint, the positive results reported by Patel are encouraging and supportive of a combined biofeedback–relaxation approach.

Weston (1974), using the constant cuff method (Shapiro *et al.*, 1969) and providing feedback for diastolic blood pressure or forehead elec-

tromyographic activity, with or without additional relaxation practice, and combinations of these modalities, obtained reductions in systolic and diastolic blood pressures in four groups of hypertensive subjects, 42 in all. Although no controlled diagnosis was made prior to acceptance in the study, these subjects were required to keep their medication and diet constant for the 8 weeks of the study. Subjects were males and females younger than 55 years of age. Mean group reductions varied between 13 and 36 mmHg for systolic and between 6 and 20 mmHg for diastolic pressures. Initial group mean systolic pressures varied between 143 and 167 mmHg, final pressures between 129 and 139 mmHg; initial mean diastolic levels were between 90 and 105 mmHg, final levels between 84 and 89 mmHg. The various treatment procedures produced roughly comparable effects, suggesting again that a generalized relaxation process may be involved. Moreover, the absence of a control group does not rule out the possibility that observed changes were due to habituation or other nonspecific effects.

Shoemaker and Tasto (1975) failed to reveal any significant reductions in blood pressure when a noncontinuous feedback procedure was used. However, there were important methodological differences in this study: The subjects had not been previously diagnosed as essential hypertensives; there was no control for medication and diet; systolic and diastolic blood pressures were recorded using a procedure similar to the Riva-Rocci method; and the feedback procedure did not provide continuous information to the subject. These authors also used tape-recorded muscular relaxation instructions as a method of treatment. Relaxation was found to be the more effective method of reducing blood pressure, resulting in mean group reductions across sessions of 4 and 5 mmHg for systolic and diastolic blood pressure, respectively, and 10 and 7 mmHg within sessions, respectively. Although the subjects' ages were not reported, initial blood pressure levels seemed to have been within normotensive range, around 137/92 mmHg. These latter factors might also account for the relatively small decreases observed.

Moeller (1973) and Moeller and Love (personal communication) hypothesized that by teaching subjects to relax their muscles, it may be possible to reduce blood pressure, which they assume is associated with increased muscle tension. Their procedure has a possible added advantage in that patients may be more likely to be able to "sense" and control their muscles (proprioceptive feedback) and thereby possibly develop a means of self-control of blood pressure outside of the laboratory. In a preliminary study by Moeller and Love, a sample of six patients with average baseline pressures of 153/110 mmHg was

given exercises that included muscle feedback and autogenic training as a means of facilitating general bodily relaxation. The training covered a period of 17 weeks. Both systolic and diastolic pressure were reduced by 13% in this program. In a larger study, Moeller (1973) replicated these findings in a sample of 36 patients. Group mean pretreatment pressures ranged between 157/102 mmHg and 169/115 mmHg; posttreatment pressures ranged from 144/91 to 154/95 mmHg, respectively, These studies did not include controls for nonspecific effects.

Benson, Rosner, Marzetta, and Klemchuk (1974a,b), using procedures based on meditation techniques in which the physiological effects seem to mimic Hess's (1957) "trophotropic" response, have shown that elicitation of what they call the "relaxation" response (Benson, Beary, & Carol, 1974; Benson, 1975) effectively reduced blood pressure levels in 14 pharmacologically treated hypertensive subjects and in 22 untreated borderline hypertensives. Although etiology of hypertension was not investigated, the group of pharmacologically treated hypertensives reduced systolic pressure from 146 to 135 mmHg and diastolic pressure from 92 to 87 mmHg (Benson *et al.*, 1974a). The pretreatment control period lasted 5.6 weeks and the experimental period 20 weeks. In the prospective study with borderline hypertensives (Benson *et al.*, 1974b), during the 6-week pretreatment control period, blood pressures averaged 147 mmHg systolic and 95 mmHg diastolic. During the subsequent 25-week experimental period, when the patients regularly elicited the relaxation response, blood pressures fell to 139 mmHg systolic and 91 mmHg diastolic. This relaxation procedure is very simple to explain and easy for patients to practice by themselves.

Datey, Deshmukh, Dalvi, and Vinekar (1969) used a yogic relaxation exercise to treat 32 essential, 12 renal, and 3 arteriosclerotic hypertensive patients (37 men, 10 women, mean age 46 years, range 22 to 64 years of age). Most of the patients on drug therapy had been under treatment for an average of about 2 years at a hypertensive clinic. During this period, their drug treatment had been stabilized, and any attempt to reduce the drug dosage caused a rise in blood pressure. The patients who had not received any antihypertensive drugs were first given placebo tablets for at least a month before learning the relaxation technique. Ten patients were not taking any drugs, 22 had their blood pressure well controlled with drugs, and in 15 blood pressure was inadequately controlled in spite of drugs. In the group of patients not taking any drugs, the average mean blood pressure was reduced from 134 mmHg to 107 mmHg. In the group of 22 patients whose blood

pressure was well controlled with drugs, the mean blood pressure was 102 mmHg. Since the blood pressure was well controlled, no attempt was made to reduce it further. The drug treatment was gradually reduced, keeping the mean blood pressure constant, and it was possible to reduce the average drug requirement to 32% of the original in 13 patients. In the remaining 9 patients in whom the drug requirement could not be [illegible]ed, 6 were irregular in performing the exercise, but 3 were reg[illegible] mean blood pressure after the yogic exercise in this [illegible]nts was about the same (102–100 mmHg). Out of 15 pa[illegible]lood pressure was inadequately controlled in spite of drug[illegible] required was reduced to 29% of the original in 6 patients. The dose was unchanged in 7 (of these, 2 were irregular and 2 could not perform the exercise correctly). The dose had to be slightly increased in two other patients who were regular in their exercise. In those cases with essential hypertension, 62.5% responded favorably to this treatment as did 42% of renal hypertensives. However, of the three patients with arteriosclerotic hypertension, none responded. The study lasted about 40 weeks.

An innovative approach to relaxation was utilized with some success in lowering pressure in patients with essential hypertension (Brady, Luborsky, & Kron, 1974). It is called "metronome-conditioned relaxation" and requires that the patient lie down for half an hour with eyes closed and listen to a tape recording (Brady, 1973). The recording consits of suggestions to "re–lax" and "let–go" of the muscles paced with rhythmic beats of an auditory metronome set at 60 beats per minute. With repeated training, several patients showed significant reductions in pressure, but the reductions were observed only during the practice periods. Two patients who used the tape recording at home for a protracted period showed further reductions in pressure.

Luthe (1963) has also described good reductions in blood pressure with the use of autogenic training, a procedure basically aimed at producing physical and psychological relaxation. It involves self-suggestions of warmth, passivity, and total bodily relaxation.

While the various behavioral procedures have all been shown to be effective in reducing high blood pressure to some degree, comparative studies are needed to determine their relative effectiveness. It is reasonable to expect that different training procedures will show up in differences in the degree and persistence of achieved self-control and in the physiological patterns associated with this control. However, the fact that the various procedures, including biofeedback, have more or less similar results suggests that a relaxation or low arousal state may be a common underlying factor (see Benson, 1975; Stoyva & Bud-

zynski, 1974). This state may well be facilitated if the patient is confident that he is able, in fact, to exert control over his own blood pressure. In a disorder as complex as hypertension, it will take a larger body of empirical studies than is currently available to be able to conclude that any particular combination of biofeedback with other methods of self-regulation is ready for routine medical practice in specific varieties of hypertension or in particular subgroups of patients. Experimental treatment programs with systematic efforts at evaluation are proceeding in a number of hospitals, clinics, and research institutes. Systematic, well-controlled studies are needed, and time will tell.

MEDICAL AND PHYSIOLOGICAL COMPLICATIONS IN ESSENTIAL HYPERTENSION

Application of biofeedback procedures in the treatment of essential hypertension is a fertile ground for clinical and basic research through the combined efforts of physiologists, physicians, psychologists, and biomedical engineers. Ideally, such work should be performed in a setting that provides adequate medical backup. The need for team work is dictated by the complexity of the cardiovascular system; subtleties in differential diagnosis of essential hypertension; required clinical knowledge of, and experience with, the disorder; medical, ethical, and legal responsibility towards the patient; and mastery of the behavioral and recording procedures to be employed in the treatment. Seldom can one single investigator deal with all of these problems by himself. For example, patients should have a thorough medical workup to rule out secondary hypertension, for which adequate treatment procedures are available. Administration of behavioral treatments carries with it the same responsibility as the prescription of medication in the case of drug treatment. Because biofeedback for blood pressure involves the treatment of disease, it is one area where traditional medical models of illness cannot be dismissed. While hypertension can be exacerbated by emotional and environmental variables, it has a distinct physical etiology and represents profound physiological dysfunction. Also, at certain stages it may be associated with permanent destruction and/or alteration of tissue, which may or may not be amenable to a behavioral amelioration. In most cases, medication will have to be used in association with biofeedback training. As Pinkerton (1973) aptly remarked, "no single factor is of overriding importance in symptom production [in psychosomatic illness]. The

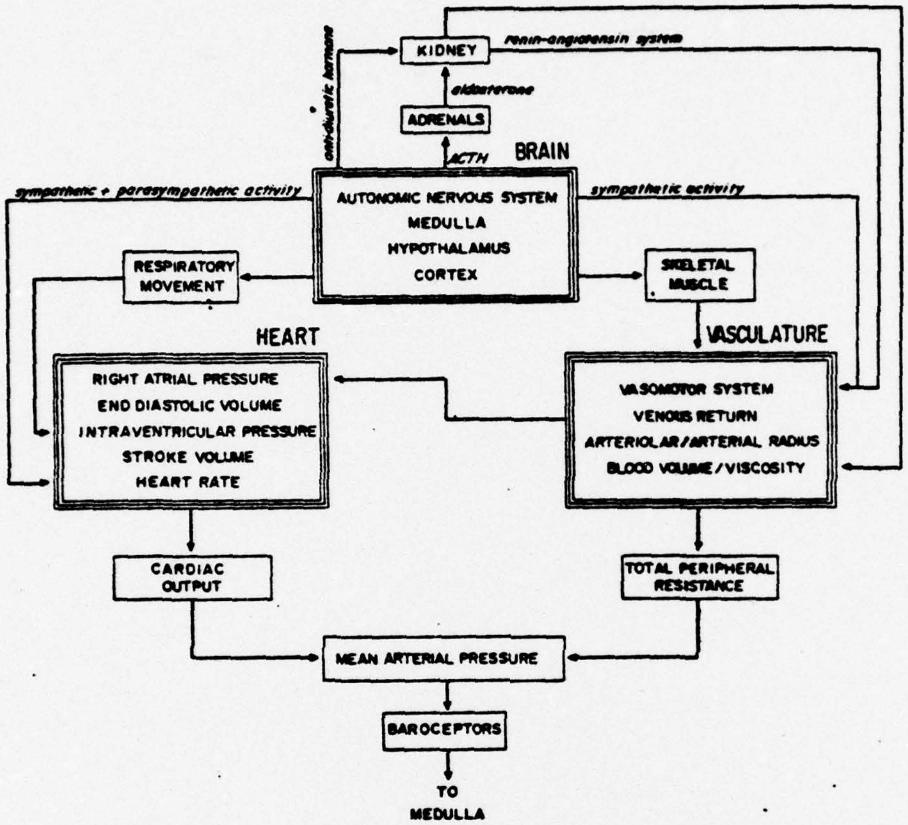

Figure 13.1 Schematic diagram summarizing the physiological mechanisms involved in the regulation of arterial blood pressure. The diagram oversimplifies the processes involved in order to provide a general overview of mechanisms most relevant to behavioral manipulation. Boxes labeled Heart, Brain, and Vasculature each contain a subset of relevant systems and functions. While these are not necessarily temporally or functionally related in the order presented, the outside arrows indicate the site at which other systems exert their influence on the system described in the box. The reader should note the numerous and diverse pathways through which behavioral control over blood pressure could be exerted. For example, relaxation techniques acting on the muscles could have their main effect on the vasculature, producing a decrease in peripheral resistance. Yogic exercises emphasizing breath control might have their main effect on cardiac output by changing intraventricular pressure. While the diagram suggests that a feedback approach including both cardiac and vascular parameters would be most efficacious, it illustrates how verbal instruction acting on the cortex might also be seen to affect blood pressure. [From "Learned control of physiological function and disease" by

clinical outcome is always determined by a composite etiological sequence, so that the key to successful management lies in correctly evaluating each factor's importance in any given case" (p. 462).

In any event, it is clearly not up to the psychologist alone to decide how biofeedback will contribute to the treatment of hypertension. Consequently, biofeedback should be applied clinically only after a competent medical diagnosis has been made, and the examining physician and biofeedback specialist have decided that biofeedback may be of value. The need for medical participation in any biofeedback case is both an ethical and legal responsibility of the psychological practitioner. Conversely, it is also the ethical responsibility of a physician who wishes to employ biofeedback in treatment to collaborate with a psychologist in designing the behavioral procedures of the proposed therapy. Medical training does not usually provide the in-depth knowledge of behavioral variables of which the practitioner must be cognizant in order for training to be successful. Therefore, the use of biofeedback in therapy for hypertension should be an endeavor involving both medical and behavioral specialists.

Figure 13.1 gives a general picture of the network of interacting systems and processes involved in the regulation of systemic arterial pressure in healthy human beings. In normal states, the cardiovascular system operates to maintain homeostasis, its principal physiological function being to provide adequate cell nutrients to the body tissues in response to actual metabolic demands. The cardiovascular system is exquisitely regulated to maintain cell nutrients proportional to tissue metabolic requirements by means of control of cardiac output, systemic arterial pressure usually remaining within narrow limits. Arterial blood pressure changes when metabolic demands are excessive, such as during exercise. Moreover, the metabolic-dependent regulation of the cardiovascular system is easily overridden by cortical or subcortical stimulation under "stress" conditions or in preparation for exercise or "action" (Brod, 1964; Folkow & Rubinstein, 1966). It is well known that systemic arterial blood pressure is significantly influenced by psychogenic factors, emotional stress, and behavioral and physiological environmental demands. Such neurogenic influences, perfectly adaptive where action follows the preparatory rise in cardiovascular activity, are not adaptive in typical life situations where

"fight" or "flight" responses are not compatible with accepted social behavior. Furthermore, neurogenic factors have often been postulated as being implicated in the hypertensive process (DeQuattro & Miura, 1973; Dustan, Tarazi, & Bravo, 1972; Pfeffer & Frohlich, 1973).

The disorder called essential hypertension (or of unknown cause) means only that blood pressure is elevated above certain arbitrary age–sex norms. The disorder tends to progress ("hypertension begets hypertension"), and the whole system stabilizes again and again around higher and higher levels of blood pressure (Rushmer, 1970). In contrast, in a normal organism, the system would compensate to reduce acute increases in blood pressure or cardiac output to normal levels. Thus, changes in one part of the cardiovascular system by means of biofeedback or other methods may produce changes in other parts of the system, whether to compensate for the imposed deviation from homeostasis, or just as associated changes. Furthermore, the nature of the readjustment depends on the particular functioning of the system in the given individual or variety of disorder.

The complexity of physiological factors thought to be involved in the development or maintenance of essential hypertension is shown in Figure 13.2. This diagram illustrates the need to be aware of the complexity of the disorder, rather than taking the oversimplified view of modifying blood pressure directly, which may or may not turn out to be the most successful approach to treatment.

In its "fixed" state, hypertension involves changes in anatomical structures; that is, the medial walls of the arteries are swollen, while neurogenic vasoconstrictor discharges are minimal or normal (Folkow, 1971; Rushmer, 1970). However, after 10 or 20 years of drug treatment, blood pressure sometimes returns to normal even after drug treatment is discontinued. This seems to support the hypothesis that hypertrophy of the medial arterial walls is reversible under conditions of reduced arterial pressure (Folkow, 1971; Folkow, Hallbäck, Lundgren, Sivertsson, & Weiss, 1973). However, the time required for such reversions to take place in humans is not known, though it may be short. The structural changes suggest that blood pressure feedback in the treatment of fixed essential hypertension might not meet much success, unless it can result in keeping blood pressure at low levels in the same way that drugs are presumed to do.

Since diastolic pressure is known to be closely associated with peripheral resistance, a possible approach to fixed hypertension would be to use biofeedback for reducing diastolic pressure while at the same time preventing compensatory increases in heart rate. This could be

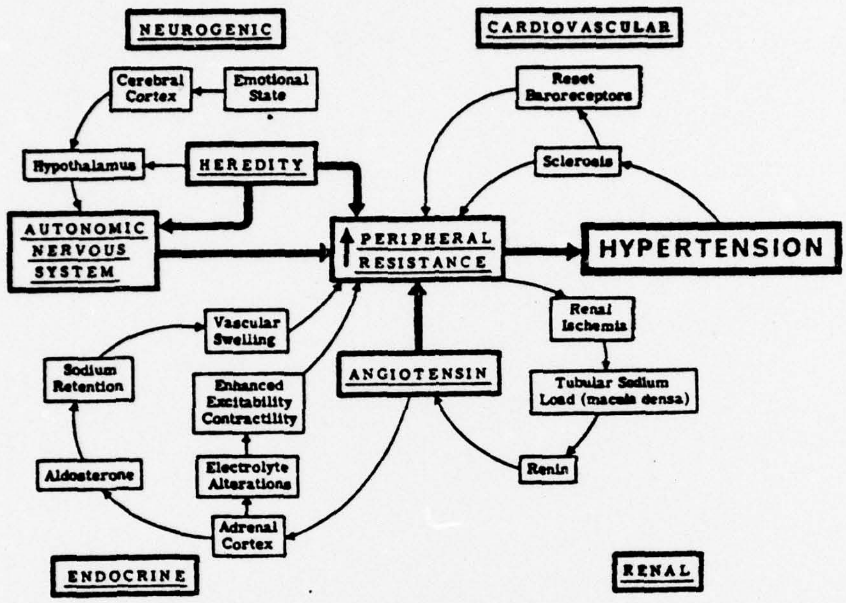

Figure 13.2 Possible participation of various factors in the development of hypertension. [From "Pathological physiology of the cardiovascular system. A. Hypertension" by J. J. Friedman, in E. E. Selkurt (Ed.), *Physiology* (3rd ed.) (Boston: Little, Brown, & Co.). © 1971 by Ewald E. Selkurt. Reprinted by permission.]

accomplished with a pattern approach in which feedback is given for a decrease in diastolic pressure except when it is associated with an increase in heart rate. The main objective in the therapy of fixed essential hypertension is to reduce blood pressure in a permanent fashion, and this implies a re-resetting of the mechanoreceptor reflex working range to normal pressure levels, as well as providing the conditions for the arterial walls to return to their normal structural characteristics. Again, much research is needed in this area, since the research of Shapiro *et al.* (1972) showed that acute reductions in diastolic pressure by means of biofeedback and operant conditioning were not accompanied by compensatory increases in heart rate. Indeed, the results of this experiment raise an important empirical question regarding behavioral–physiological interactions in intact organisms which is not clearly explained by traditional physiology, namely, how does behavioral modification of individual cardiovascular parameters affect the total function of the cardiovascular system in an intact organism? For a

discussion of compensatory changes in cardiovascular responses resulting from controlled physiological manipulation of selected parameters, see Rushmer (1970, Chap. 3) and Rothe and Friedman (1971).

There are also reports in the literature (DeQuattro & Miura, 1973; Schmid & Abboud, 1974) indicating that some cases of fixed essential hypertension are characterized by elevated sympathetic activity. Direct recording of sympathetic activity in specific neural pathways is a field now in its infancy (Wallin, Delius, & Hagbarth, 1973), and we are not yet technologically and theoretically sophisticated enough to undertake modifications of sympathetic activity in specific pathways, such as selectively modifying parameters of cardiac function and/or of peripheral circulation. A combination of relaxation techniques and blood pressure feedback might turn out to be effective for such patients. Indeed, even if sympathetic smooth muscle arteriolar tone is normal or subnormal in fixed essential hypertension, a procedure (such as general relaxation, meditation, or biofeedback) that can produce an *active* inhibition of "normal" sympathetic tone may facilitate reduction in peripheral resistance and, consequently, blood pressure. Continuous practice of such a procedure might accomplish the desired result, especially if the patient also changes his whole mode of responsiveness to environmental events.

Many investigators believe that fixed essential hypertension develops as a compensatory process in response to idiopathic, high cardiac output states (Guyton, Coleman, Bower, & Granger, 1970). The process apparently develops in genetically predisposed young adults who are cardiovascular hyperreactors under emotional or environmental stress (Eich, Cuddy, Smulyan, & Lyons, 1966; Forsyth, 1974; Frohlich, Kozul, Tarazi, & Dustan, 1970; Frohlich *et al.*, 1969; Gorlin, Brachfeld, Turner, Messer, & Salazar, 1959; Tobian, 1972). Consequently preventive treatment of this prehypertensive high cardiac output state may turn out to be the treatment of choice. This stage of hypertension is also known as "labile" essential hypertension because it is often accompanied by large variability in blood pressure and/or hyperresponsiveness to stimuli of various sorts. The main physiological derangement in "labile" hypertension is an increased cardiac output, with or without correspondent abnormal increases in blood pressure. Total peripheral resistance often remains "abnormally normal"; that is, it fails to decrease in order to compensate for the high cardiac output. Treatment of the disorder at this stage thus requires monitoring of cardiac output or associated cardiovascular indices. Biofeedback training for such indices of relevant cardiac functioning

would likely be advantageous in this disorder. However, the development of adequate noninvasive methods of recording cardiac output and other critical cardiovascular indices presents a major challenge for investigators in the field (see Obrist, Black, Brener, & DiCara, 1974). A now-feasible alternative possibility in labile patients who have significantly elevated heart rates is biofeedback training for simultaneous decreases in heart rate and systolic pressure.

Though it has not been proved that labile hypertension is a necessary and sufficient condition for the transition to fixed essential hypertension to occur, this prehypertensive state represents an area of research where biofeedback procedures might be most useful. Indeed, labile hypertension and the hyperkinetic syndromes in general may be especially amenable to behavioral treatment because important neurogenic factors seem to be involved in their etiology (Frohlich *et al.*, 1970; Schmid & Abboud, 1974). At the present time, this large at-risk population (Freis, 1972, 1974) remains basically untreated, since the risk of later development of fixed hypertension is not clearly known.

An alternative approach of significance for the control of blood pressure in labile hypertension might be a decrease of total sympathetic activity. General physiological functions, such as sympathetic activity, may be more readily subject to "voluntary" control because they involve a number of common nervous pathways that are integrated at higher levels of the nervous system. That biofeedback training may be used to modify patterns of simultaneous change in two (and possibly more) physiological functions is illustrated in the research of Schwartz (1972). He found that patterns of heart rate and blood pressure could be modified. Moreover, larger decreases (or increases) in both heart rate and systolic blood pressure were found when feedback and rewards were given for the simultaneous occurrence of decreases (or increases) in both, as compared to earlier results when only one or the other function was reinforced (Shapiro *et al.*, 1970b). The strategy of training may be to go from the general to the specific, at first utilizing as many common sympathetic functions as possible and then selectively controlling those responses most related to pressure reduction. Irrelevant responses in the global pattern would then drop out as training progresses (Kimble & Perlmuter, 1970).

An effective way to modify blood pressure in either labile or fixed essential hypertension might be through the control of higher cortical activity, such as in meditation (Benson, 1975). The process may have its effect by direct downstream control of subcortical centers and,

hence, autonomic activity. Since this process requires that the patient focus his attention and maintain a specific cognitive set, it is not certain how its therapeutic effects might generalize during the day when normal cortical pressures are occurring. In contrast to the feedback approach, the effectiveness of meditation would seem to be predicated upon producing an all-encompassing change in the hypertensive patient's behavior. This suggests that it is not reasonable to reduce blood pressure alone while leaving the remainder of a high stress behavioral repertoire intact.

The above-mentioned variations in approaches, findings, and theories concerning the physiological derangement underlying idiopathic high blood pressure, together with several abnormalities in plasma renin activity and levels of circulating catecholamines, illustrate the point that several subcategories of hypertension are masked under the heading of "essential." We have speculated on a number of different biofeedback strategies that may be useful in addition to those already applied in clinical studies. Clearly, clinical practice and research in this area will benefit greatly from long-term intensive case studies, where careful observations and thorough evaluations are the rule.

Finally, we should point out that there are many factors affecting blood pressure levels which need to be adequately controlled, if not accounted for, during clinical trials and research (Pickering, 1968):

1. posture
2. muscle activity and strenuous exercise
3. emotional states and current life stress
4. place of recording (home, clinic, emergency room)
5. professional status of person recording blood pressure (self, relative, nurse, student, physician)
6. spontaneous variability—familiarity with or habituation to the treatment environment
7. accumulation of urine in the bladder ("bladder reflex")
8. respiratory maneuvers and patterns
9. time of day
10. basal metabolic versus nonbasal conditions
11. time and amount of last food or liquid taken
12. diet

A brief look at the above partial list again underscores the complexity of the problem. It suggests at the least that blood pressure recordings and feedback training should occur at the same time of the day and in the same social setting. Several baseline sessions are needed in

order to allow for habituation effects to wear out and to determine the patient's characteristic blood pressure and other important physiological functions (e.g., heart rate, respiration) before starting treatment. Also to be considered are weight, age, sex, and ethnic and socioeconomic background of the patient. Of great importance are prescription, change, or discontinuance of medication concurrent with behavioral treatments and the use of appropriate criteria, beyond mere blood pressure readings, in diagnosis, treatment, and evaluation. It is obvious that all of these factors cannot be experimentally or statistically controlled for. They should all be considered in addition to a thorough hypertensive workup. They add to the complicated picture of hypertension in its various phases, and emphasize the need for a comprehensive approach to treatment and research.

Furthermore, not only is control of the above variables desirable, but their therapeutic potential might well be tapped independently of or in conjunction with other means of behavioral intervention. For example, current life stress or other social factors influencing blood pressure might be attended to by means of counseling, psychotherapy, behavior therapy, or direct alterations in life style or occupation. As discussed previously, changes in muscle tension and respiratory patterns can be approached by means of biofeedback, meditation, or other behavioral methods. Similarly, biofeedback procedures might be used to decrease spontaneous variability of blood pressure or of other variables related to blood pressure, for example, heart rate and respiration. Regarding diet, it is well known that dietary prescriptions concerning caloric, salt, and cholesterol intake are often part of conventional hypertensive treatment.

SOME PRACTICAL CLINICAL ISSUES

The first, and perhaps most obvious, question of practical concern in the evaluation of biofeedback as a clinical tool in the treatment of hypertension is economy. How much time and effort on the part of both the patient and the practitioner is needed to obtain a clinically useful result? Even if biofeedback techniques can be shown to be therapeutically effective, what patient would opt for a costly time-consuming training course if equal reduction of blood pressure could be obtained from pills? Unless the side effects of the medication are serious or biofeedback is shown to be superior to medication, it is unlikely that biofeedback will be considered as a treatment of choice.

A related issue has to do with patient motivation. Several articles

(e.g., Schwartz, 1973; Schwartz & Shapiro, 1973; Shapiro & Schwartz, 1972; Surwit, 1973) have commented on the importance of patient motivation in biofeedback programs. It is not sufficient to assume that feedback indicating therapeutic improvement will, in and of itself, act as a reinforcer and maintain the persistent practice required to gain therapeutic benefit. Hypertension has no short-term aversive consequences. It usually works its insidious destruction within the cardiovascular system without causing any serious discomfort to the patient. By the time a painful heart attack occurs, it may be too late to correct the damage. It is only the knowledge that the patient has hypertension and that the disorder is not good for him that provides motivation to undergo treatment. In light of the fact that many hypertensive patients will not even take their medication regularly, it is uncertain whether biofeedback training, requiring long periods of practice, will prove generally useful. It depends, of course, on how really successful biofeedback methods turn out to be.

A second possible area of motivational difficulty arises from other behaviors strongly entrenched in the patient's repertoire that may be in conflict with the aims of therapy. This is best illustrated in a case discussed by Schwartz (1973). A patient was treated for essential hypertension and, over a week of treatment, lowered his blood pressure by as much as 20 mmHg. Over the weekend, his pressure would become elevated again. The difficulty turned out to be that the patient liked to gamble on weekends and persisted in doing so despite the fact that such activities were countertherapeutic. This last point is extremely important. There is good evidence that certain schedules of reinforcement for somatomotor behaviors can induce high blood pressure in normal animals (Benson *et al*., 1969; Benson, Herd, Morse, & Kelleher, 1970; Brady, 1958; Harris *et al*., 1973; Morse *et al*., 1971). It would seem futile to attempt to treat a disorder with biofeedback training unless work were also done on analyzing and correcting behavioral processes that may be associated with the problem.

An issue closely related to motivation and equally important in the successful application of biofeedback techniques to hypertension is transfer of training. It is often all too easy to forget, even for psychologists, that learning techniques cannot be administered as are most medical treatments. There is no reason to believe that biofeedback, in and of itself, like radiation therapy and diathermy, can be expected to produce sustained effects outside of the treatment session. It is completely logical that a patient may show perfect control over his problem during a feedback session and no control at home. In basic research in normal subjects, some investigators have explored the use of intermittent reinforcement schedules as an aid to generalization

(Greene, 1966; Shapiro & Crider, 1967; Shapiro & Watanabe, 1971), but the evidence is insufficient to conclude that partial reinforcement increases resistance to extinction in the case of visceral responses, such as learned reductions of blood pressure in the laboratory. In their study of the control of premature ventricular contractions, Weiss and Engel (1971) phased the feedback out gradually, making it available all the time at first, then 1 minute on and 1 minute off, then 1 on and 3 off, and finally 1 on and 7 off. The purpose of the procedure was to wean the patient from the feedback and enable him to become more aware of the arrhythmia through his own sensations and to become less dependent upon the feedback. Hefferline and Bruno (1971) described a similar technique of slowly fading out the feedback as a means of transferring external to internal control. There is also evidence for the short-term maintenance of learned control of diastolic pressure (Shapiro *et al.*, 1972), but the need is great for comprehensive research on extinction and reconditioning processes in autonomic learning and on self-regulation without feedback.

A related, but more complex, issue concerns the need of patients to control their reactivity to stressful stimuli or situations. In most cases, biofeedback procedures are applied in resting, nonstimulating laboratory settings. Will the patient be able to transfer this training to the relevant situations in everyday life? Patel (1975) has reported that, with a combination of yoga exercises and biofeedback, patients were able to lower their systolic and diastolic pressures during both rest and in response to everyday emotional stresses. Working with heart rate, Sirota, Schwartz, and Shapiro (1974) showed that, in anticipation of receiving noxious electrical stimulation, subjects learned to control their heart rate when provided with external heart rate feedback and reward for appropriate changes. Voluntary slowing of heart rate led to a relative reduction in the perceived aversiveness of the noxious stimuli, particularly for those subjects who reported experiencing cardiac reactions to fear situations in their daily lives. Sirota *et al.* concluded:

> Taken together, the results support the general conclusion that direct feedback control of autonomic functions which are appropriate for given subjects in terms of their normal fear responding and/or whose relevance for fear has been instructionally induced may possibly be used in systematic desensitization to inhibit anxiety from occurring in response to phobic stimuli and as an adjunct to other therapeutic techniques for the prevention and reduction of anxiety and fear reactions. [1974, p. 266]

Procedures such as these should be studied as a means of increasing the potential for greater transfer of learned control of blood pressure to relevant situations for the individual.

In addition to motivation, Shapiro and Schwartz (1972) have pointed out that patient characteristics must also be considered in determining the feasibility of biofeedback as a treatment. Because most clinical and experimental work on biofeedback has been done with highly educated, motivated individuals, it is at present unclear how the variables of intelligence, socioeconomic status, and overall life adjustment are related to treatment outcome. Until more data shed light on these questions, therapists should be cognizant of the particular characteristics of the population from which successful behavior therapy patients have been drawn.

Finally, in a previous review (Shapiro & Surwit, 1976), it was concluded, "There is *not one* well-controlled scientific study of the effectiveness of biofeedback and operant conditioning in treating a particular physiological disorder." We are not so sure now about the prerequisites of such a study in biofeedback research, especially given the complexities and varieties of a disorder such as hypertension. Moreover, the evaluation of placebo and nonspecific effects is particularly troublesome in behavioral treatment situations, which involve repeated contacts of a positive and cooperative nature between doctor and patient. Unlike drug studies in which a pill can be handled with either single- or double-blind methods, a behavioral treatment is not so easily manageable. Various beliefs, biases, and attitudes in either patient or doctor, either initially or in the course of intercommunication during treatment, can easily complicate administration or evaluation of particular experimental or control procedures. With these considerations in mind, single group and crossover designs are still possible in which various biofeedback and behavioral procedures can be applied singly or in various combinations and compared with commonly accepted medical treatments (drugs). At a later stage of research, it should also be possible to devise placebo treatments involving levels of attention, contact, and personal relationship that are comparable to those employed in biofeedback and related methods. This research will require a great deal of ingenuity, care, and effort. It will also require adequate financial support. As emphasized previously, clinical research in this area will also gain from intensive case studies involving careful observations, thorough evaluations, and good documentation.

CONCLUSION

In one of the first reports of the use of biofeedback in the regulation of blood pressure in humans, it was concluded, "The apparatus and

results suggest a possible approach to the treatment of essential hypertension" (Shapiro *et al.*, 1969, p. 588). In the interim, both basic and clinical research have moved us closer to the realization of this goal. Unlike other, more specific or unitary physiological responses that have been studied in biofeedback experiments, blood pressure is a complex biological function involving biochemical, humoral, central, and autonomic nervous system processes. Yet, despite its complexity, blood pressure appears to function like some of the other, simpler physiological responses in regard to behavioral interventions. Thus, changes in blood pressure, either separately or in combination with heart rate, can be modified by means of biofeedback and reinforcement. This apparent selectivity in the control of cardiovascular patterns is of particular significance, given the complexity of the entire cardiovascular system and the various homeostatic systems of regulation. To facilitate clinical application of biofeedback in the control of blood pressure, we obviously need to know a great deal more about the cardiovascular system in response to various biofeedback techniques and other means of behavioral regulation of different cardiovascular and associated physiological indices. Biofeedback offers a valuable research tool in investigating such processes in the intact organism.

Not only is blood pressure a complex biological function, but so is essential hypertension a disorder that involves many different physiological, behavioral, and environmental processes. Knowledge of the disorder in its various stages and varieties is essential to an eventual practical behavioral therapy. We have tried to outline some of the salient facts about the disorder, and have speculated about particular physiological and behavioral approaches to clinical application. A slowly growing body of research indicates that biofeedback techniques can produce significant reductions in blood pressure in patients with essential hypertension or result in reductions of antihypertensive medications. The techniques also have been effectively applied in conjunction with other behavioral, cognitive, and physiological methods. Systematic comparative studies are needed to determine which behavioral interventions are most critical in achieving therapeutic benefits.

We believe that the attractiveness of biofeedback and other behavioral procedures lies in that they might provide alternative or adjunctive modalities in the treatment of high blood pressure, thereby perhaps increasing patient compliance and satisfaction and maximizing the effectiveness of, or providing alternatives to, drug therapy. Again, a word of caution. The research to date suggests, though as yet does not conclusively demonstrate, the effectiveness of biofeedback

and other behavioral techniques in the treatment of high blood pressure. The behavioral studies reported so far are simply basic demonstrations. Long-term effects and the feasibility of implementation of behavioral procedures need to be thoroughly investigated. We are hopeful that continued systematic research and sound clinical practice will bring us still closer to converting biofeedback and other behavioral approaches into accepted medical practices. Through interdisciplinary efforts, this area of research will contribute significantly to our basic understanding of psychosomatic interactions and, hopefully, lead to practical applications in clinical medicine.

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